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Schaenzer

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[54] **OPTICAL DATA STORAGE SYSTEM WITH IMPROVED HEAD LENS ASSEMBLY**

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Related U.S. Application Data

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[51] **Int. Cl.**[7] **G02B 7/02**; G11B 7/00

[52] **U.S. Cl.** **359/819**; 369/112; 369/44.23

[58] **Field of Search** 359/819, 808; 369/112

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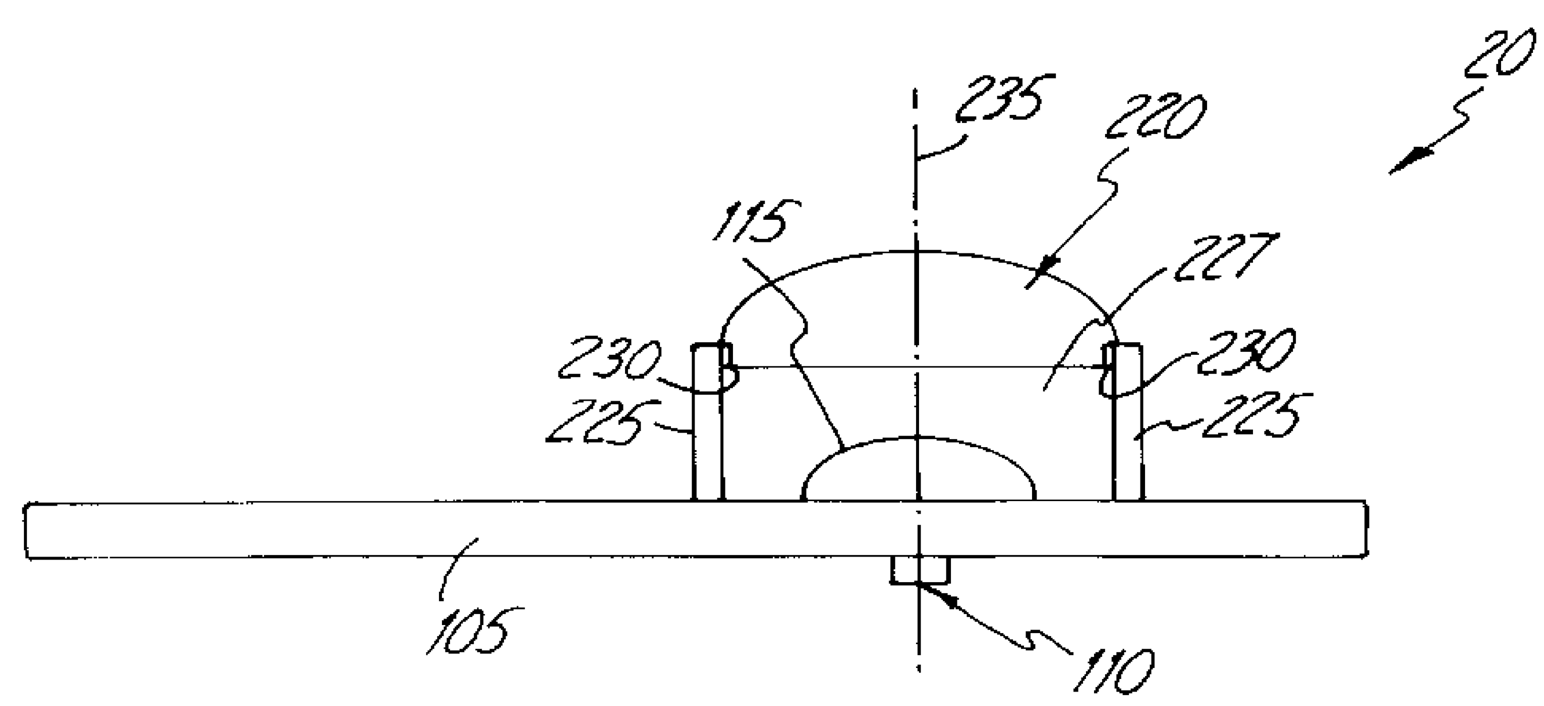
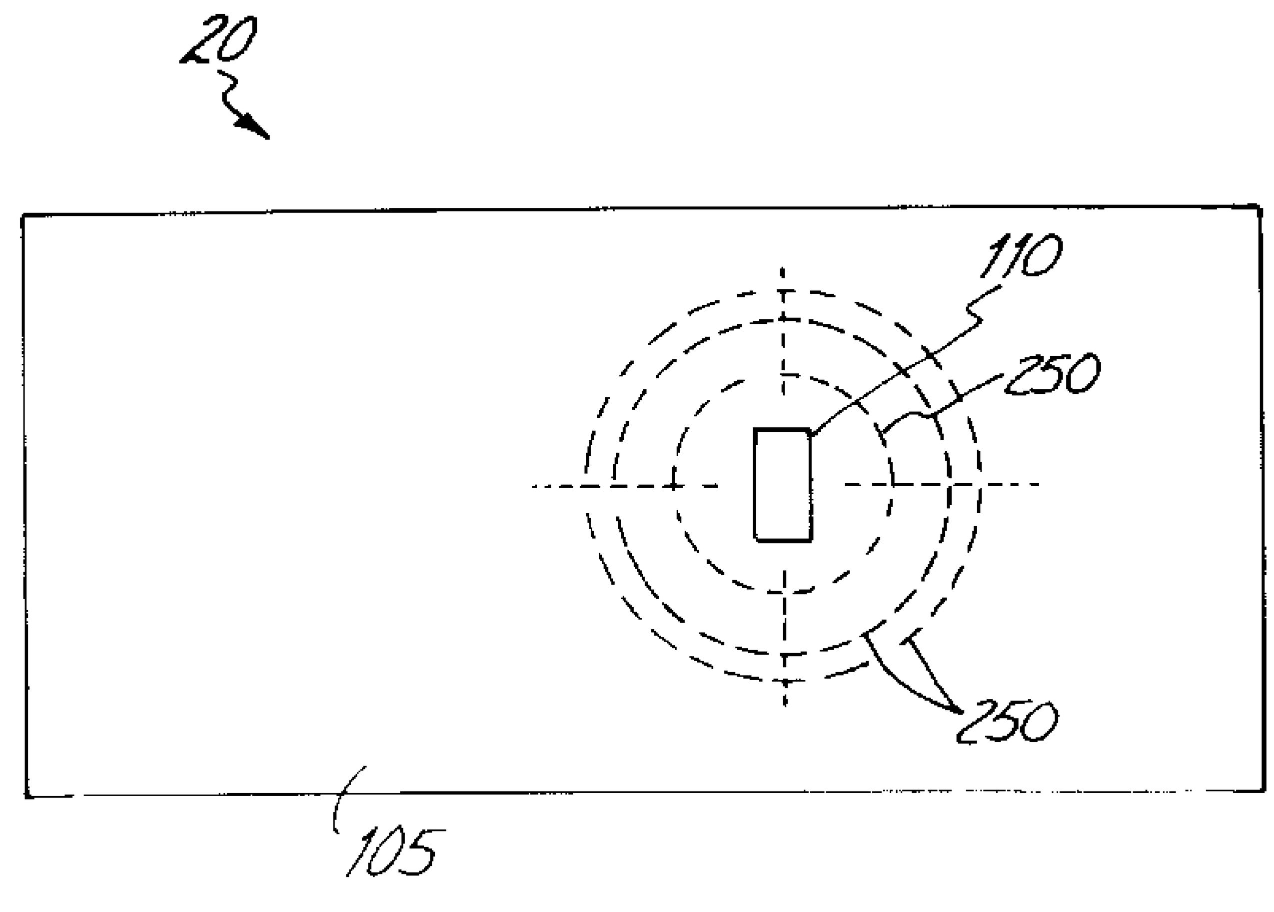
Attorney, Agent, or Firm—Westman, Champlin & Kelly, P.A.

[57] **ABSTRACT**

An optical data storage system and a method of assembling the same are disclosed. The storage system includes an optical disc having a data surface, a transducing mechanism including an objective lens, a slider positioned adjacent the data surface, and a lens mount coupled to the slider and to the objective lens and supporting the objective lens relative to the slider. The lens mount forms an aperture in which the objective lens is at least partially inserted. First and second slots formed in the lens mount provide lateral access to the objective lens in the aperture for adjusting a position of the objective lens within the aperture.

14 Claims, 4 Drawing Sheets





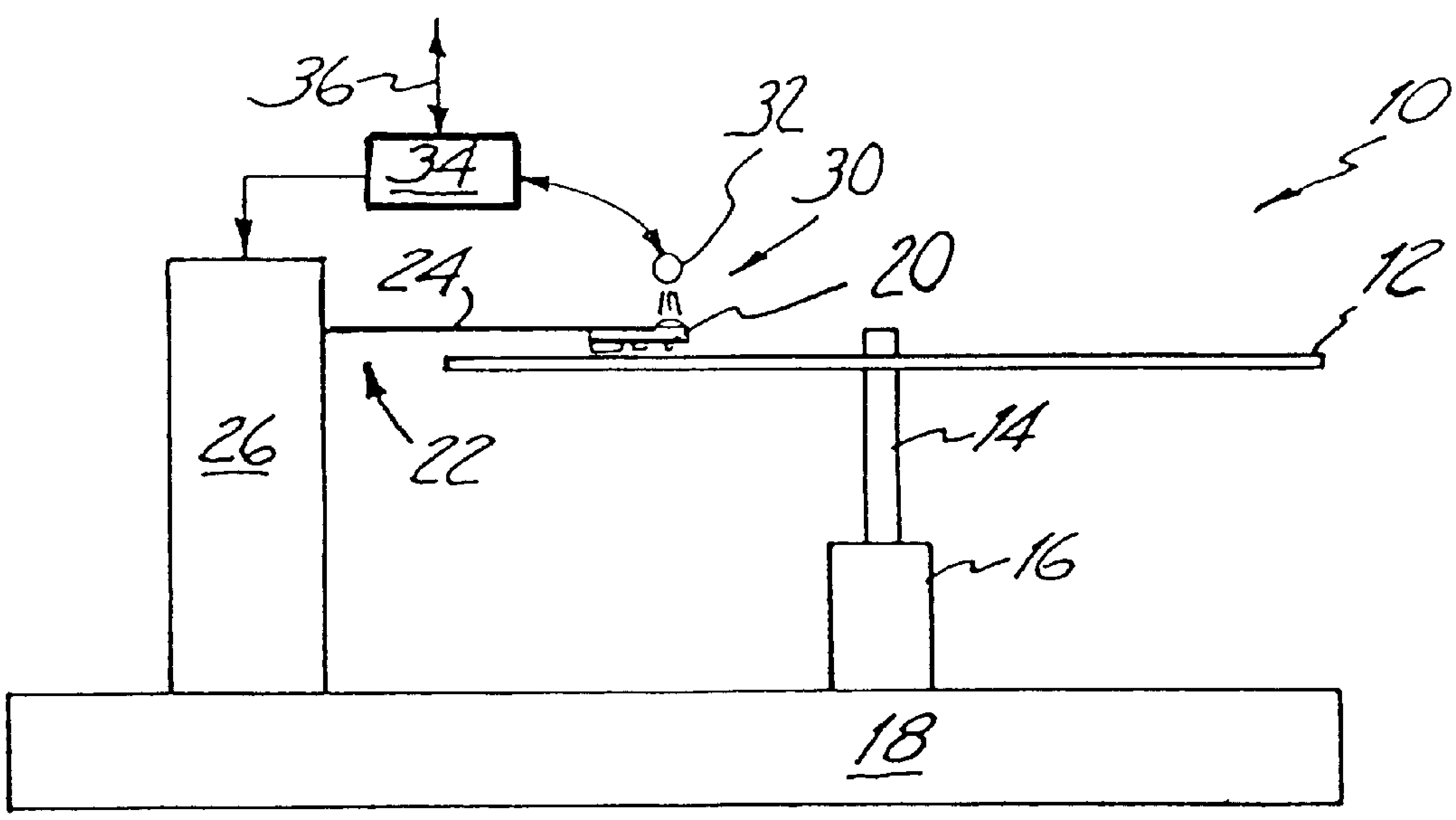


Fig. 1

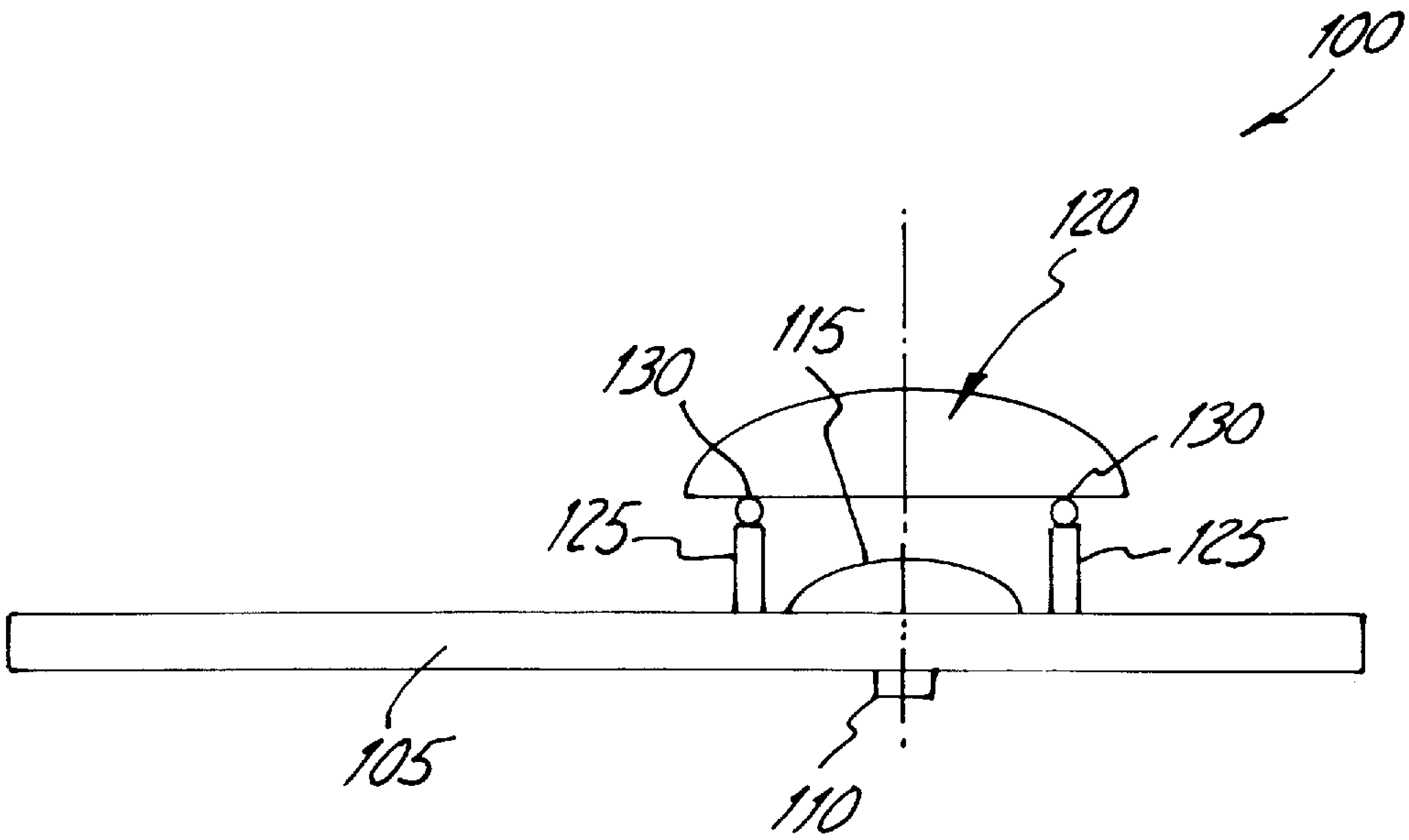


Fig. 2 PRIOR ART

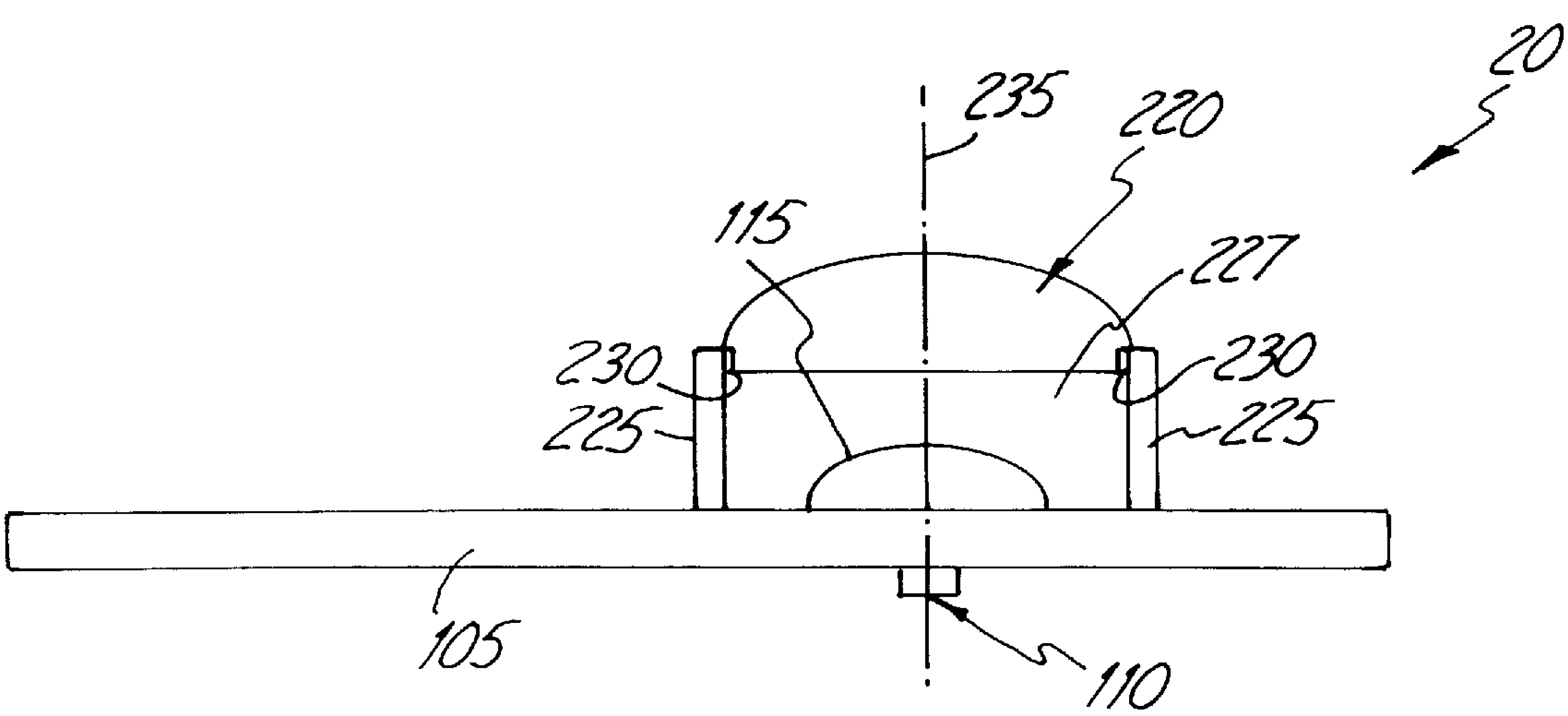


Fig. 3

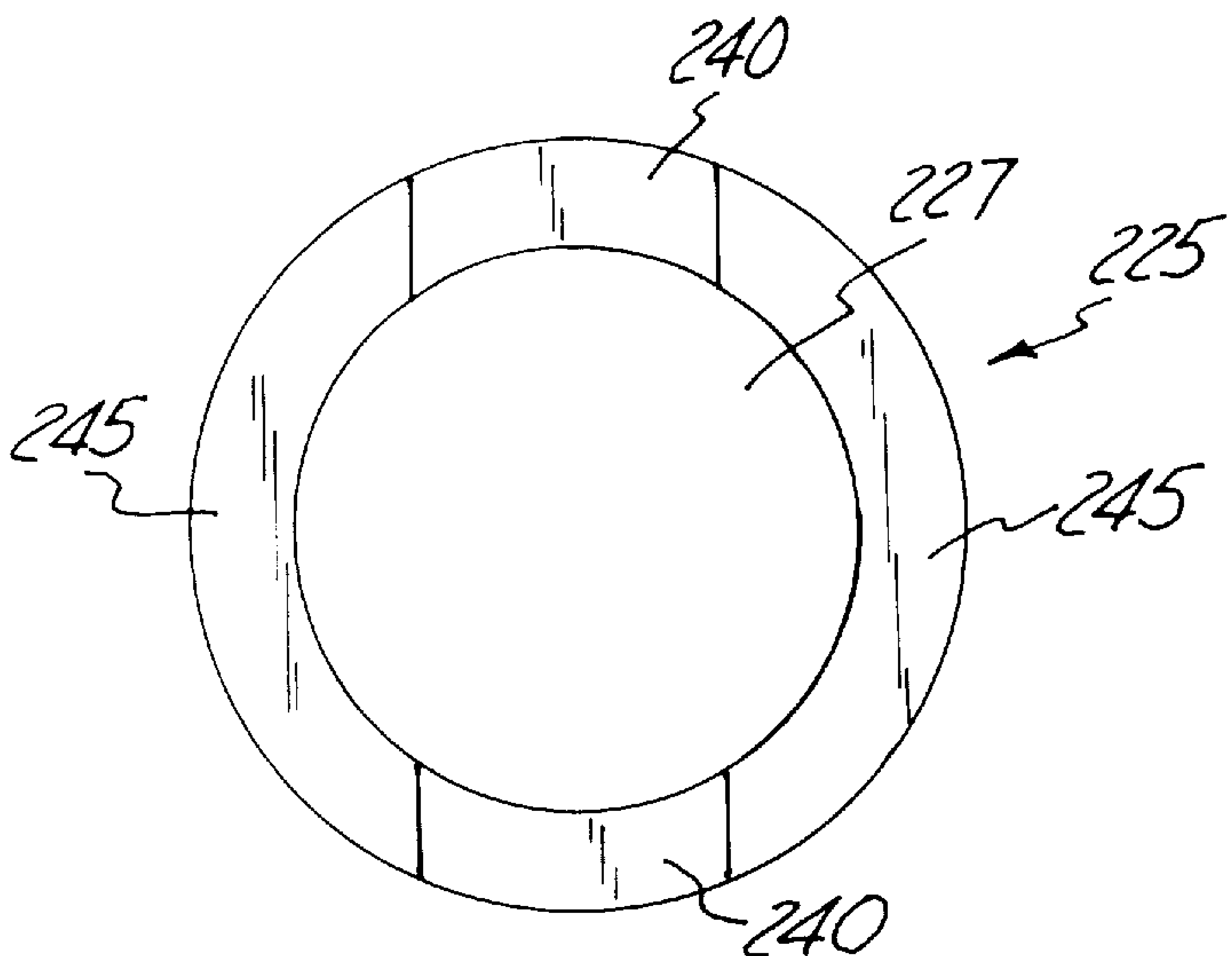


Fig. 4

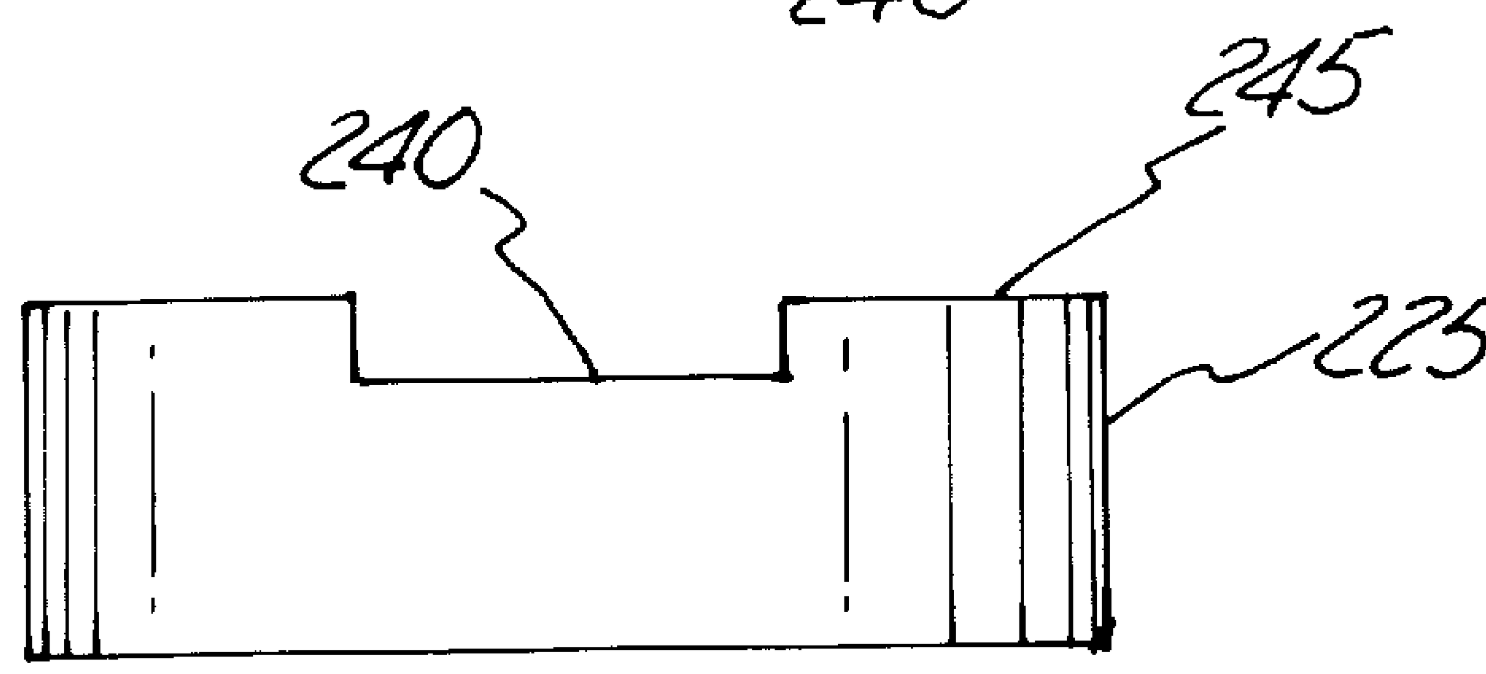


Fig. 5

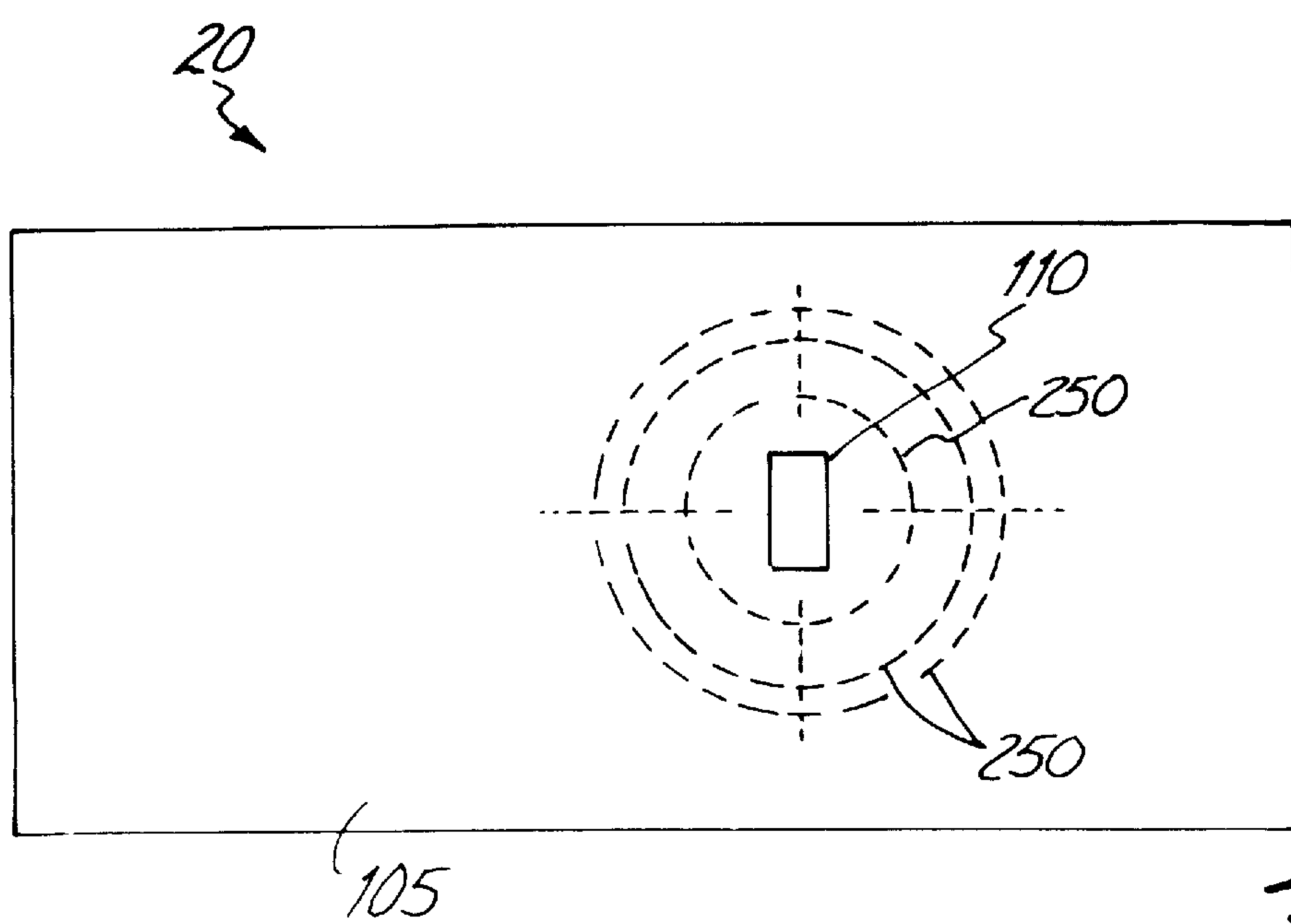
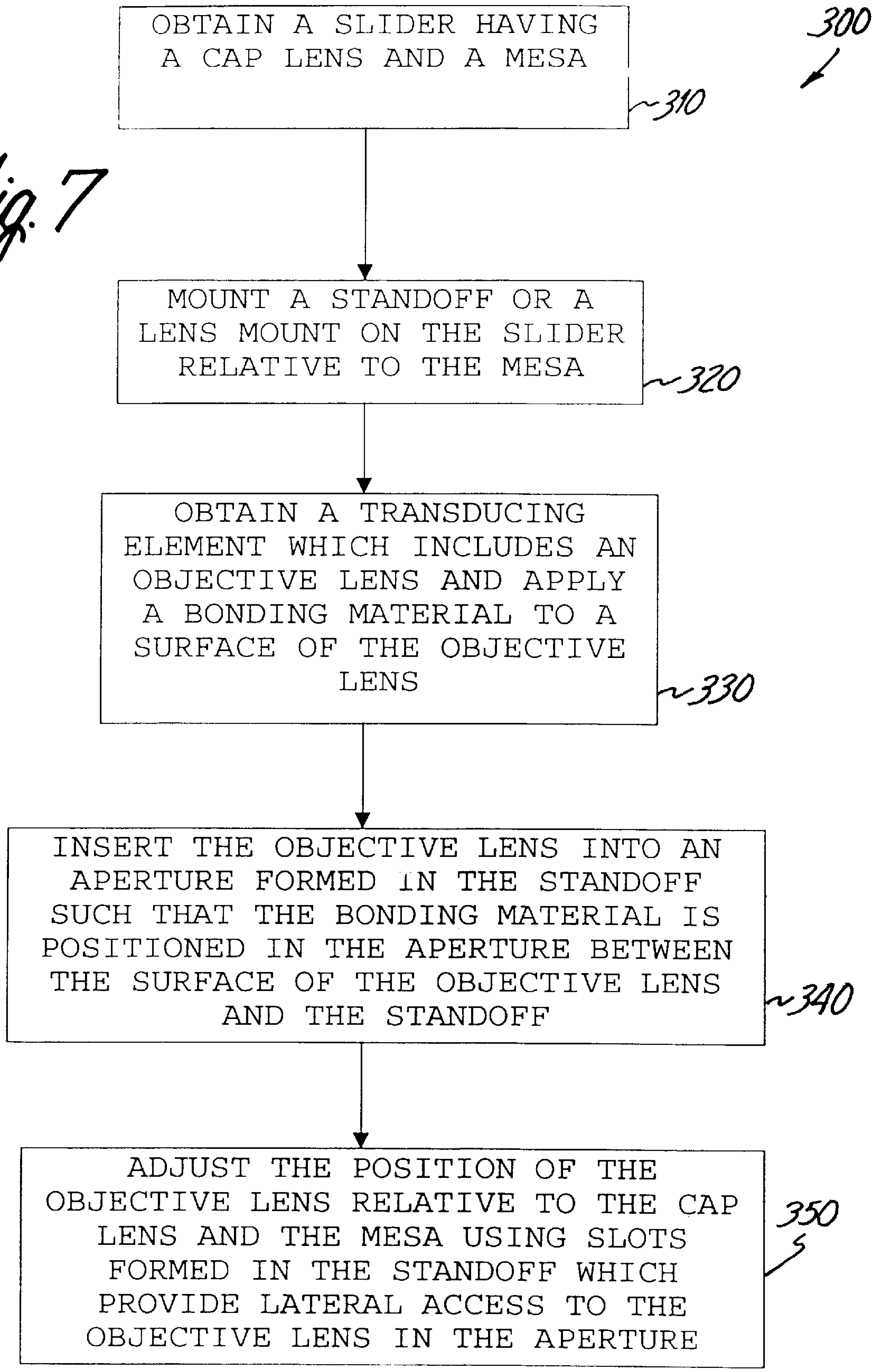


Fig. 6

Fig. 7


300
OBTAIN A SLIDER HAVING A CAP LENS AND A MESA
310
MOUNT A STANDOFF OR A LENS MOUNT ON THE SLIDER RELATIVE TO THE MESA
320
OBTAIN A TRANSDUCING ELEMENT WHICH INCLUDES AN OBJECTIVE LENS AND APPLY A BONDING MATERIAL TO A SURFACE OF THE OBJECTIVE LENS
330
INSERT THE OBJECTIVE LENS INTO AN APERTURE FORMED IN THE STANDOFF SUCH THAT THE BONDING MATERIAL IS POSITIONED IN THE APERTURE BETWEEN THE SURFACE OF THE OBJECTIVE LENS AND THE STANDOFF
340
ADJUST THE POSITION OF THE OBJECTIVE LENS RELATIVE TO THE CAP LENS AND THE MESA USING SLOTS FORMED IN THE STANDOFF WHICH PROVIDE LATERAL ACCESS TO THE OBJECTIVE LENS IN THE APERTURE
350

OPTICAL DATA STORAGE SYSTEM WITH IMPROVED HEAD LENS ASSEMBLY

The present invention claims priority to Provisional Application Serial No. 60/071,809, filed Jan. 20, 1998 and entitled IMPROVED OPTICAL HEAD LENS ASSEMBLY, herein incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to optical data storage systems. More specifically, the present invention relates to optical data storage systems which include an objective lens coupled to a slider.

Optical data storage disc systems are a promising technology for storing large quantities of data. The data is accessed by focusing a laser beam onto a data surface of the disc and analyzing light reflected from or transmitted through the data surface. In general, in optical storage systems, data is in the form of marks carried on the surface of the disc which are detected using the reflected laser light. There are a number of different optical disc technologies which are known in the industry. For example, compact discs are currently used to store digital data such as computer programs or digitized music. Typically, compact discs are permanently recorded during manufacture. Another type of optical system is a write-once read-many (WORM) system in which a user may permanently write information onto a blank disc. Other types of systems are erasable, such as phase change and magneto-optic (M-O) systems. Phase change systems detect data by sensing a change in reflectivity. M-O systems read data by measuring the rotation of the incident light polarization due to the storage medium.

The above systems require a beam of light to be focused onto a data surface of a disc and recovering the reflected light. Storage density is determined not only be the size of the markings on the data surface, but also by the size of the beam focused on the surface (i.e. resolution). One type of optical element which can be used in conjunction with an objective lens to reduce the ultimate spot size of the light beam is a Solid Immersion Lens or SIL. A SIL, which is sometimes referred to as a cap lens, reduces the beam spot size by virtue of the wavelength reduction which occurs when light is inside an optically dense medium. The SIL is positioned very close to the data surface of the disc and couples light to the disc surface via evanescent wave effects. This is often referred to as the "near-field" regime. The use of SILs for data storage is described in U.S. Pat. No. 5,125,750 to Corle et al. which issued Jun. 30, 1992 and in U.S. Pat. No. 5,497,359 to Mamin et al. which issued Mar. 5, 1996. In these optical systems, a laser beam is focused onto the SIL using an objective lens. The SIL is preferably carried on a slider and the slider is positioned close to the disc data surface.

One difficulty encountered in prior art near field recording heads is correctly focussing light from an optical source onto the data surface of the storage medium. For example, in near field recording heads in which the objective lens of the optical lens assembly is mounted on top of a lens mount or standoff using epoxy, a problem arises when the optical assembly is exposed to different temperatures. The coefficient of expansion of the epoxy allows it to expand beyond the total tolerance between the objective and cap lenses, thereby changing the alignment of the objective lens and adversely affecting the focus.

SUMMARY OF THE INVENTION

An optical data storage system and a method of assembling the same are disclosed. The storage system includes an optical disc having a data surface, a transducing mechanism including an objective lens, a slider positioned adjacent the data surface, and a lens mount coupled to the slider and to the objective lens and supporting the objective lens relative to the slider. The lens mount forms an aperture in which the objective lens is at least partially inserted. First and second slots formed in the lens mount provide lateral access to the objective lens in the aperture for adjusting a position of the objective lens within the aperture. A bonding material is positioned in the aperture between the objective lens and the lens mount such that a change in a distance between the objective lens and a second lens mounted on the slider is minimized during thermal expansion of the bonding material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified diagram showing an optical storage system using a lens mount in accordance with one embodiment of the present invention.

FIG. **2** is a simplified diagram showing a prior art optical head slider having an objective lens mounted to the slider in a conventional manner.

FIG. **3** is a simplified diagram showing an optical head slider having an objective lens mounted to the slider in accordance with the present invention.

FIG. **4** is a top view of one embodiment of the lens mount or standoff illustrated in FIG. **3**.

FIG. **5** is a side view of the lens mount or standoff illustrated in FIGS. **3** and **4**.

FIG. **6** is a simplified diagram showing a bottom view of the optical head slider illustrated in FIG. **3**.

FIG. **7** is a flow diagram illustrating a method of assembling the optical head sliders of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a simplified illustration of an optical recording system **10** employing a cap lens or Solid Immersion Lens (SIL) and a lens mount in accordance with the present invention. System **10** includes optical disc **12** having a data surface which carries optically encoded information. Disc **12** rotates about spindle **14** and is driven by a spindle motor **16** mounted on base **18**. A slider **20** is positioned proximate disc **12** and is coupled to an actuator **22** which includes armature **24** and actuator motor **26** which couples to base **18**. Slider **20** includes optical elements or lens assembly **30** in accordance with the present invention. Optical lens assembly **30** typically includes an objective lens, a lens mount or standoff, and a SIL or cap lens. An optical source/sensor apparatus **32** is optically coupled to elements **30** through a mirror or other mechanism. A controller **34** couples to apparatus **32**, actuator **26** and data bus **36** and is used for controlling operation of system **10**. Although not shown, slider **20** in a near field recording head can include a magnetic coil for writing data onto disc **12**.

During operation, disc **12** rotates and slider **20** is positioned radially over the data surface of disc **12** using actuator **22**. Controller **34** controls the position of slider **20**, whereby information may be read from (and in some embodiments written to) the data surface of disc **12** using optical source/sensor apparatus **32** and optical lens assembly **30**. Precise control of spot position is achieved by controller **34** scanning the spot across the disc surface over several tracks. For example, this could be by moving a mirror between optical source/sensor apparatus **32** and optical lens assembly **30**.

The precise configuration of apparatus of **32** may be selected based upon the type of storage system **10** employed. In general, source/sensor apparatus **32** includes an optical source which directs light toward optical elements **30** for illuminating the data surface of disc **12**. Light is reflected back through optical elements **30** from the data surface of disc **12** for detection by apparatus **32**. Controller **34** senses the reflected signal which is converted to data for transmission on data bus **36**.

FIG. **2** is an elevation view of a portion of a prior art optical head **100**. Prior art optical head **100** includes slider body **105**, slider mesa **110**, SIL or cap lens **115**, objective lens **120**, and standoff or lens mount **125**. There are two critical alignments in prior art slider **100**. First, cap lens **115** is aligned to slider mesa **110**. Standoff **125** is "roughly" aligned to cap lens **115** and serves as support for objective lens **120**. Objective lens **120** is aligned to cap lens **115**. The height of the objective lens to the cap lens is critical for the focus of the objective lens. To accomplish the height alignment, a bead **130** of epoxy, nominally 75 uM thick, is used to support the objective lens. The epoxy is cured with a UV light source as the objective lens is held in relation to the cap lens.

The alignment between the objective lens and the cap lens is critical for the focus and spot size of the laser. The focus requires that the distance between the objective lens and the cap lens be maintained to around one micron. The problem arises when the optical assembly is exposed to a temperature range which is constant with the operating conditions of the typical storage device. The epoxy used for this application has a typical thermal expansion coefficient of 200×10^{-6}. For a temperature range of 100 degrees C. (−40 to 60 C.) this corresponds to an expected range of motion of 1.5 uM (given a 75 uM epoxy bond line). The total assembly tolerance for the objective lens to the cap lens is given at ±0.25 uM. As can be seen, the epoxy alone accounts for three times the accepted tolerance.

A critical flaw in the above assembly is the 75 uM bead of epoxy. Epoxies by nature have a fairly high thermal coefficient of expansion. The proposed solution to this problem is to mechanically integrate the objective lens and the standoff. This is accomplished by making the standoff taller and making the objective lens cylindrical. The objective lens is then slid inside of the standoff. Epoxy is then used to bond the objective lens to the standoff. To provide for the focus adjustment and to minimize the thermal expansion of the epoxy, the preferred embodiment of the present invention described below can be used.

FIG. **3** illustrates a first preferred embodiment of optical head slider **20** in accordance with the present invention. In the embodiment illustrated in FIG. **3**, head slider **20** includes slider body **105**, slider mesa **110**, cap lens or SIL **115**, objective lens **220**, lens mount or standoff **225** and bonding material **230**. Slider body **105** is preferably made from a transparent material. With cap lens **115** properly aligned relative to mesa **110** and optical path **235**, standoff **225** is mounted or secured to slider body **105**. Bonding material **230**, such as a UV curable epoxy, is deposited on an outer surface of objective lens **220**. In a preferred embodiment, objective lens **220** is cylindrical in shape, as is standoff **225**. Objective lens **220** is then inserted into aperture **227** formed in standoff **225** such that bonding material **230** is positioned laterally between objective lens **220** and standoff **225**. Thus, thermal expansion or contraction of bonding material **230** will push or pull on standoff **225**, but will not raise or lower objective lens **220** in the direction of optical path **235**.

Standoff **225** can be fabricated to allow the objective lens **220** to be held and adjusted in height relative to cap lens **115**.

This is accomplished by "notching" the standoff as illustrated in FIGS. **4** and **5**. Standoff **225** is cylindrical in shape and includes notches or slots **240** between wing regions **245**. Notches **240** provide lateral access to objective lens **220** for use in moving objective lens **220** up and down within aperture **227** along optical path **235**. Preferably, standoff **225** and objective lens **220** are fabricated such that the clearance between them is less than 25 uM. Because the epoxy **230** is placed between the objective lens and the standoff in a lateral direction (substantially perpendicular to the direction of optical path **235**), the expansion and contraction does not raise and lower the objective lens. The expansion and contraction will pull or push on the wings **245** of the standoff. Although only one slot **240** is shown, multiple slots can be used.

During the objective lens assembly process slots **240** in the standoff provide an area to hold the edges of objective lens **220**. This allows the accurate assembly of the objective lens to cap lens **115**. Once the proper height is established, then the UV curable epoxy is activated with a UV light source.

Another consideration to this assembly process is locating the standoff relative to the cap lens. Since the cap lens is set relative to mesa **110**, alignment targets **250** are provided for assembling both the cap lens and the standoff relative to the slider mesa. Targets **250** are illustrated in the bottom view of FIG. **6**. These targets can be fabricated using the photolithography process which is used to fabricate slider mesa **110**.

Targets **250** can be designed for use with machine vision to facilitate the automated assembly of the cap lens and the standoff. Because slider body **105** is preferably clear, targets **250** can be fabricated on the top or bottom of the slider body. FIG. **6** illustrates one of many possible target designs. The final target design and location (on the top or bottom of the slider body) is best determined by considering the photolithography processes and machine vision acquisition optimization.

FIG. **7** is a flow diagram illustrating one preferred method of assembling the optical heads of the present invention. As illustrated, at block **310**, a slider designed to move adjacent a data surface of an optical storage medium is obtained. The slider has a cap lens and a mesa. At block **320**, a lens mount or standoff is mounted on the slider relative to the mesa. Mounting the standoff on the slider relative to the mesa can include mounting the standoff on the slider using a first target formed on the slider in a position which facilitates alignment of the standoff relative to the mesa. Further, mounting the standoff can be implemented using an automated process to mount the standoff on the slider. The automated process would preferably use machine vision and the first target to align the standoff relative to the mesa.

At block **330**, a transducing element which includes an objective lens is obtained. A bonding material, for example UV curable epoxy, is applied to a surface of the objective lens.

At block **340**, the objective lens is inserted into an aperture formed in the standoff such that the bonding material is positioned in the aperture between the surface of the objective lens and the standoff. The bonding material is preferably positioned in lateral directions, perpendicular to the direction of the optical path, between the objective lens and the standoff. At block **350**, the position of the objective lens relative to the cap lens and the mesa is adjusted using slots formed in the standoff which provide lateral access to the objective lens in the aperture. Adjusting the position of the objective lens relative to the cap lens and the mesa using the slots formed in the standoff typically includes laterally accessing the objective lens positioned in the aperture using the slots to thereby adjust an insertion distance of the objective lens into the aperture. Once the position of the objective lens is adjusted as desired, the bonding material is cured to maintain the objective lens in the adjusted position.

A primary benefit of this improved assembly process is the improved thermal performance of the optical assembly. The assembly process outlined allows for current assembly processes to assemble the objective lens relative to the cap lens. Also the current epoxy can also be used. Standoff **225** is fabricated using molding or machining processes. The effect of the thermal expansion is minimized by maintaining the size differential between the objective lens and the standoff less than 25 uM.

The alignment targets facilitate the alignment of the cap lens to the mesa and the standoff to the cap lens. The alignment targets also enable the use of automated assembly including machine vision systems. These targets are easily fabricated as part of the slider fabrication process without the need for an additional fabrication step. Seed layers are used as part of the bond pad process (on the top of the slider) and also as part of the cavity etching process (on the bottom of the slider).

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. An optical data storage system, comprising:

an optical disc having a data surface;

a transducing mechanism including an objective lens;

a slider positioned adjacent the data surface;

a lens mount coupled to the slider and to the objective lens and supporting the objective lens relative to the slider, the lens mount forming an aperture in which the objective lens is at least partially inserted, the lens mount also forming first and second slots providing lateral access to the objective lens in the aperture;

a second lens coupled to the slider;

a slider mesa positioned on the slider;

a first target formed on the slider in a position which facilitates alignment of the second lens relative to the mesa; and

a second target formed on the slider in a position which facilitates alignment of the lens mount relative to the mesa.

2. The optical data storage system of claim **1**, wherein the slots are disposed opposite one another on the lens mount.

3. The optical data storage system of claim **2**, wherein the lens mount is a cylindrical lens mount.

4. The optical storage system of claim **2**, wherein the objective lens is focused on the second lens.

5. The optical data storage system of claim **4**, wherein the second lens comprises a Solid Immersion Lens (SIL).

6. The optical data storage system of claim **4**, and further comprising a bonding material positioned between the objective lens and the lens mount in the aperture to secure the objective lens to the lens mount, the bonding material being positioned relative to the objective lens and the lens mount such that a change in a distance between the objective lens and a the second lens coupled to the slider is minimized during thermal expansion of the bonding material.

7. The optical data storage system of claim **6**, wherein the bonding material is epoxy.

8. The optical data storage system of claim **6**, wherein the first and second targets are photolithography formed targets adapted for identification by machine vision to facilitate an automated assembly of the second lens and the slider mount relative to the slider mesa.

9. A method of manufacturing an optical storage system, comprising:

obtaining a slider designed to move adjacent a data surface of an optical storage medium, the slider having a cap lens and a mesa positioned thereon;

mounting a standoff on the slider relative to the mesa using a first target formed on the slider in a position which facilitates alignment of the standoff relative to the mesa;

obtaining a transducing element which includes an objective lens;

applying a bonding material to a surface of the objective lens;

inserting the objective lens into an aperture formed in the standoff such that the bonding material is positioned in the aperture between the surface of the objective lens and the standoff; and

adjusting a position of the objective lens relative to the cap lens and the mesa using slots formed in the standoff which provide lateral access to the objective lens in the aperture.

10. The method of claim **9**, wherein mounting the standoff on the slider further comprises using an automated process to mount the standoff on the slider, the automated process including using machine vision and the first target to align the standoff relative to the mesa.

11. The method of claim **9**, wherein adjusting the position of the objective lens relative to the cap lens and the mesa using slots formed in the standoff further includes laterally accessing the objective lens positioned in the aperture using the slots to thereby adjust an inserting distance of the objective lens into the aperture.

12. The method of claim **11**, and further comprising curing the bonding material once the position of the objective lens is adjusted to maintain the objective lens in the adjusted position.

13. The method of claim **12**, wherein the bonding material is an epoxy and curing the bonding material further comprises activating the epoxy with a UV light source.

14. An optical data storage system, comprising:

an optical disc having a data surface;

a transducing mechanism including an objective lens;

a slider positioned adjacent the data surface; and

a lens mount coupled to the slider and to the objective lens, the lens mount forming an aperture in which the objective lens is a t least partially inserted and wherein the objective lens is supported relative to the slider solely by an adhesive applied to the lens mount and objective, lens, the lens mount also forming first and second slots providing lateral access to the objective lens in the aperture.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,023,378
DATED : February 8, 2000
INVENTOR(S) : Mark J. Schaenzer

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 6, line 59, after "objective" delete "," first occurrence.

Signed and Sealed this

Twenty-fourth Day of April, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer *Acting Director of the United States Patent and Trademark Office*